The Effects of Canopy Density and Vegetative Competition on Oak Seedling Numbers in Southeastern Ohio

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Abstract

The regeneration of oak species in the forest setting has been a current issue for foresters. Oak-hickory forests are currently the dominant cover type in most parts of the Eastern Hardwood Region, but the lack of regeneration in the understory is hinting toward a reduction in the number of oaks. The data shows the oaks are regenerating as seedlings but there are few oaks in the sapling stage. The oaks do not occur in the sapling stage as the result of the oak seedlings are succumbing to competition by other vegetation at young ages. This study focused on how canopy cover and the competing vegetation affected oak seedlings in a natural forest. The competing vegetation showed that as red maple and other hardwoods species increase in numbers and canopy area, the less oak seedlings that are present in the seedling category.

Introduction

Oaks (*Quercus* spp.) are one of the most important tree species in the Eastern United States. The many different species of oaks are used for a wide range of purposes including but are not limited to timber, wildlife and aesthetic values. Regenerating northern red oak (Quercus *rubra* L.) is a silvicultural problem across the species wide geographic range (Crow 1988). Several factors are the cause of this problem, including competition between oak seedlings and other tree species. The most common competitors are shade intolerant species such as sassafras (*Sassafras albidum* N.) and yellow poplar (*Liriodendron tulipifera* L.). These shade intolerant species quickly out compete oaks in growth and suppress the oak, causing the seedlings to have high mortality rates. Red maple (*Acer rubrum* L.), a shade tolerant species, reproduces in abundant numbers and persists in the understory and mid-canopy, adding to this competition (Abrams 1998).

One factor contributing to the decline of oaks in the forest ecosystem is related to the amount of light that reaches the forest floor. Since the settlement of North America, the natural disturbances in the forests have been reduced greatly. Light regimes vary significantly within small forest openings, ranging from full sunlight to total shade, which may affect the establishment and early growth of oak seedlings (Guo et al. 2001). The sunlight that reaches the forest floor is directly related to the forest canopy opening. The denser the canopy of the forest, the less light that will penetrate to the forest floor. This denser canopy favors shade tolerant species and discriminates against the more light-demanding oaks (Dodge 1997). The amount of sunlight the seedlings receive is also related to the basal area of the forest. Higher basal areas generate a greater likelihood of a denser canopy cover, resulting in less sunlight reaching the forest floor. White oaks have been shown to produce more acorns when the canopy of the forest is less dense. This increased acorn production leads to a potential increase in the amount of oak regeneration (Stringer 2002).

The many species of oak trees provide a multitude of wildlife species with food and shelter. The oak-hickory forest types in Ohio and eastern states are shifting to a forest with more red maple and yellow poplar (Iverson et al. 2004). A recent problem in natural stands of timber is the lack of oaks in the sapling stage. There is often oak regeneration under mature forest canopies but the seedlings are too small to compete with the taller saplings of other species (Lorimer 1994). The oaks decline in number as they move from seedling to sapling size in the understories of mature forests. This gap in the regeneration of the oaks is most likely caused by the stand structureand the interruptions humans have caused in the natural disturbance cycle (Ross et al. 1982).

Oaks are normally a moderately shade intolerant species. This is one reason why it is difficult for oak seedlings to become established in the dense shade of the understory of a mature forest. The right amount of shade has to be present for oaks to regenerate and become competitive with shade tolerant species. According to the central hardwoods stocking charts (Gingrich 1967), approximately 60% stocking in the main canopy should be satisfactory for the establishment of oaks (Sander 1979). This stocking level should allow ample light to reach the forest floor to regenerate oaks and restrict the establishment and growth of most competitors (Sander 1979). The forest canopies that are less than 60% stocking have the better chance of regenerating oaks in the understory. This condition can occur when there are openings in the canopy caused by fallen trees, insect damage and storm damage. These openings allow for the oak seedlings to have the partial shading needed to keep the tree competitive with other tree species.

Usually the shade intolerant species such as yellow poplar, sassafras and bigtooth aspen (*Populus grandidentata* Michx.) can out-compete oaks for resources and sunlight. Without any intervention the oaks will soon be overtopped by the shade intolerant species and succumb to competition. To keep oaks competitive on productive sites, competition needs to be controlled and stem form needs to improve along with height growth (Brose and Van Lear 1998). There are five methods when used together that assure a higher probability in regenerating oaks: 1) reducing competing vegetation; 2) reduction of forest overstories; 3) having sufficient oak seedlings in the understory; 4) managing the seedlings; and 5) removing the overstory once the new stand is established (Crow 1988).

There are three main factors that influence oak regeneration: 1) amount of light; 2) soil moisture; and 3) competition of surrounding vegetation (Sander et al. 1984, Ross et al. 1986, Carvell and Tryon 1961). The amount of sunlight that reaches the forest floor is a major factor on how well oak regenerate. Oak seedlings are shade intolerant to intermediate in tolerance and are unable to survive well under a closed canopy (Smith 1992). Oak regeneration will fail to be successful when there are high overstory and understory densities because the low light levels don't favor oak regeneration (Carvell and Tryon 1961, Ross et. al. 1986).

The height of the seedlings also plays a key role in oak regeneration. An oak stand is established when the saplings are above the deer browse height of 4 to 5 ft (Sander 1971). The established oak seedlings are more responsive to increases in sunlight and are better able to utilize its resources than younger and smaller seedlings. The established seedlings are less likely to be dramatically affected by animal and insect damage. The older seedlings have stored resources that allow them to respond and resprout if damage does occur. Accordingly a new stand may possibly not become established until it is 4 to 5 ft in height.

Methods

Site Description

The study was located at two state forests in southeastern Ohio: Zaleski and Richland Furnace. The Zaleski State Forest is located in Vinton County and is 75 miles southeast of Columbus, Ohio (82° 25' W, 39° 18' N). The Richland Furnace State Forest is located in Jackson County and Vinton County and 70 miles southeast of Columbus, Ohio (82° 25' W, 39° 18' N). These sites were chosen because little to no timber harvesting has occurred on these locations for nearly 100 years, so the forest is naturally regenerating with little disturbance and interference. The forest ecosystem cover type in both forests is predominantly oak-hickory with the dominant species in the canopy being of the oak species. The vegetation plots were measured on a wide range of aspects and the forests consist of hillsides and coves. The stocking level of these forests is near 100%, meaning the forest floor does not receive much sunlight. Also the majority of the stands are located on medium black oak (*Quercus velutina* L.) quality sites.

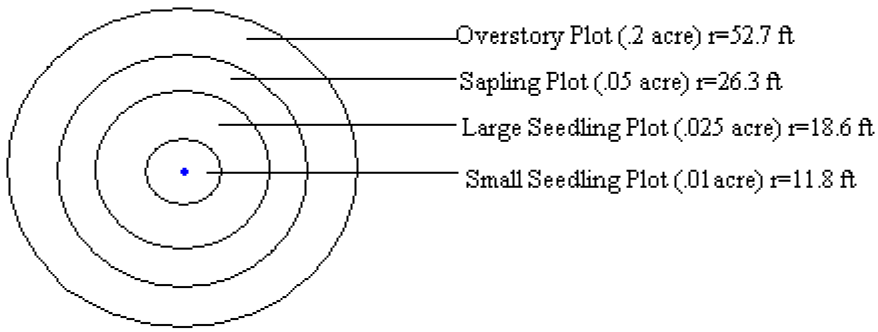
At each of the state forests there are five separate locations of where the data was collected. Each of these five locations was approximately 25 acres in size. Within each of these five locations eight measurement plots were established. The total number of plots taken at both study sites was 72, Richland Furnace had 40 plots and Zaleski had 32 plots taken. Zaleski had eight less plots due to time restrictions that did not allow for all the data to be entered into the computer format. Each vegetation plot was marked with a wooden stake and surveyor's tape flagging, to ensure the plot centers could be relocated in the future. Also each stake had a numbering system so the researcher will know were they are located with in the state forest boundary lines.

<u>Plot Vegetation and Measurement</u>

A systematic method was used to establish the plot locations rather than a random sampling method. The systematic method of locating the treatment plots throughout the treatment area allowed the plots to be evenly distributed. A systematic method of placing overstory plots at a distance of 3 chains apart on transects that and are located 3.5 chains apart was implemented. Transects were installed parallel to the grade of the slope. This method provided a sampling intensity of 6% for the overstory plots, 2% for the sapling plots, 0.08% for large seedling plots and .003% for the small seedling plots. While these intensities may seem low, the number of plots was sufficient to capture the description of understory vegetation for oak forests in southern Ohio.

Fixed area plots were used to gather the data. Each plot contains four concentric circles imbedded with one another ranging from smallest to largest (Figure 1).

Figure 1



Representation of each vegetation plot taken, the plot center is depicted by the blue center dot. The size of the plots were determined by a fixed area and then the radius was measured for each smaller plot and marked by surveyor's tape flagging at the four corners.

The center of the plot, the small seedling plot circle, had an area of .01 acre and measured the number of seedlings by species under a foot in height. The second circle was the large seedling plot circle and had an area of .025 acre. The large seedling plot measured trees that were taller than a foot but less than 4.5 feet in height. The trees that were in this range were measured for species, total height and the minimum and maximum of the large seedling crown surface area. The plot circles overlap one another so the large seedling plot also includes the area measured by the small seedling plot. This process occurred each time the plot size was expanded, the larger circle enclosed the area previously measured. Then the whole area of the larger circle was measured again according to the vegetation requirements for that plot. The third circle was the sapling plot circle and had an area of .05 acre. The sapling plot measured trees that were taller than 4.5 feet and less than 4 inches in diameter. The trees within this plot were measured for species, total height, diameter at breast height (DBH) and the minimum and maximum of the sapling crown surface area. The fourth and final circle was the overstory plot and had an area of .2 acre. The overstory plot measured any tree within the plot that was above 4 DBH. Each tree that was measured in this plot was also numbered by the use of florescent orange spray paint. The trees in this plot were measured for species, total height, DBH, minimum and maximum of the crown canopy and also the crown class of the tree. The crown class of the trees in the canopy was identified as dominant, codominant, intermediate or overtopped. The position of the oaks crown data helped determine how well of an acorn producer the tree was and also how healthy and competitive the oaks are on the different sites. Also, the plots in the state forests were permanently marked in order for future research to be conducted on the same plots.

The canopy density of the stand was taken at the four corners of each plot with a densitometer. The densitometer showed how much sunlight was penetrating the forest canopy and reaching the forest floor. These four corners where the densitometer readings were taken were located in the cardinal directions of north, east, south and west. These readings were then averaged together to give the canopy opening for that particular plot. This data showed the difference in light reaching the forest floor in the different parts of the forest.

Data Analysis

The initial field data for Richland Furnace State Forest was gathered during the spring of 2005. The data collection started at that time due to the reason it was after the bud break on the trees had occurred and an accurate densitometer reading could be measured. The field data for Zaleski State Forest was then gathered during the summer of 2005. The majority of the data was gathered by graduate and undergraduate students, who have had previous background and knowledge of forest inventorying.

The field data collected from the two state forests was entered into to the Excel Program in order to allow for the different calculations to be calculated and to find the similarities and differences in the data. The tree species were divided into the following four categories: red oak, white oak, red maple and other (Figure 2). The categories are broad due to the reason that the research is focusing on how oaks are affected by competition and different canopy closures, so specific tree species did not need to be deciphered. The red oak and white oak categories contained the species in that family group. Any species that did not fit in the previous three categories were placed into the others column, which included all woody vegetation in the understory, as these were considered competition for the oak seedlings.

Figure 2

Tree Categories: Species in each group

Red Oak
black oak (*Quercus velutina* Lam.)
northern red oak (*Quercus rubra* Michx.)
scarlet oak (*Quercus coccinea* Muenchh.)

White Oak
chestnut oak (*Quercus prinus* L.)
white oak (*Quercus alba* L.)

Red Maple
red maple (*Acer rubrum* L.)

Other
American chestnut (*Castanea dentata* Mill.)
Arrow-wood (*Viburnum recognitum* Fern.)
beech (*Fagus grandifolia* Ehrh.)
bigtooth aspen (*Populus grandidentata* Michx.)
blackgum (*Nyssa sylvatica* Marsh.)
black-haw (*Viburnum prunifolium* L.)
flowering dogwood (*Cornus florida* L.)
green ash (*Fraxinus pennsylvanica* Vahl.)
hazel (*Corylus americana* Walt.)
hop-hornbeam (*Ostrya virginiana* Mill.)
maple-leaf viburnum (V*iburnum acerifolium* L.)
mockernut hickory (*Carya tomentosa* Nutt.)
pignut hickory (*Carya glabra* Mill.)
sassafras (*Sassafras albidum* Nutt.)
serviceberry (*Amelanchier arborea* Michx.)
sourwood (*Oxydendrum arboreum* L.)
sugar maple (*Acer saccharum* Marsh.)
white ash (*Fraxinus americana* L.)
witch-hazel (*Hamamelis virginiana* L.)
yellow poplar (*Liriodendron tulipifera* L.)

Tree species recorded during data collection in both Richland Furnace State Forest and Zaleski State Forest.

The average number of trees per acre and average height were determined for both the large seedlings and sapling size for all four species groups by plot. The average height of the trees on each plot was determined by species groups. The canopy opening was recorded instead of the canopy closure because the state forests were mature stands that had a closed canopy, thus making it more time efficient to count the open squares on the densitometer. Also in the Excel spread sheets was the average crown surface area of both the large seedlings and sapling category. The average surface area was calculated by first taking the square root of the minimum crown area times the maximum crown surface area, giving the diameter of the crown area. Then the diameter of the crown area is put into the quadratic mean formula, pi*(diameter/2)^2, giving the answer of surface area. For each species category the surface areas for each tree were added together and the divided by the total number of trees in that category, giving the average surface area for canopy cover for that particular tree species for that plot.

The data was then transferred into the SAS system to perform analysis of variances (ANOVA). The different tests were calculated by grouping the plots by the opening of the crown class at the plot. Two general types of models were calculated through the SAS system. The first model focused on each of the crown class openings using the Duncan's MRT Grouping method on the four tree specie categories to see if a significant difference between the average heights and average numbers of the large seedlings and saplings exist. The second model to be tested in the SAS System were the canopy surface area regressions. These were used to show if the competition from other species is affecting the oak regeneration on the forest floor.

Results

After the initial data had been collected one apparent observation could be seen without even computing any tests. This observation was the lack of oak species in the sapling stage of the forest. The overstory of the state forests was dominated by both red oak and white oak species, which were healthy, mast producing trees. Also there was a significant amount of small seedling and large seedling oaks growing in the understory. This situation means the mature oaks are producing acorns that are regenerating on the forest floor. But then after a few years the seedlings are not receiving enough sunlight and are dying out before they can reach the sapling stage. The most abundant species in the sapling stage was red maple and black gum (*Nyssa sylvatica* Marsh.). In the Zaleski State Forest many of the large seedlings in the other category were sassafras and maple leaf viburnum (*Viburnum acerifolium* L.). This larger number of competing vegetation may have also had an affect of the oaks lower seedling numbers.

The closure of the crown class and its affects on oak large seedlings and sapling in the understory was the main focus of this study. The crown class openings that were determined at each plot with a densitometer were divided into three main groups. The three categories chosen for crown class opening percent was from 0 to 10%, 10.1 to 20% and 20.1 to 30%, these three categories for open class were called, 10, 20 and 30 respectively. The data used was from 69 of the 72 total plots and the 3 plots that could not be used were due to errors in the data collection. The following is the number of plots in each crown class opening; 28 plots in the 10 class, 33 plots in the 20 class and 8 plots in the 30 class.

The first data to be tested with the Duncan's MRT involved all the plots. The plots were not yet divided into their respective crown class opening groups, so all 69 plots were used. The tests looked at how the species groups were different from one another. It focused on the different heights and number of trees between the species for large seedling and saplings (Table 1). The results show that there is a difference between the species. There were significantly larger numbers in the large seedling stem test and with the sapling stems and height tests. The results show the others and the red maples are a great deal larger than the red oak and white oak numbers. The only category that did not show much difference was the height of the large seedlings; the seedlings were all relatively close in height.

Within each of these crown class openings the Duncan's MRT Grouping method was used on the four tree specie categories to see if a significant difference between the average heights and average numbers of the large seedlings and saplings exist. According to the Duncan's MRT Grouping the numbers that are being tested are significantly different when the letters with the corresponding numbers are different. If the letters are the same, then there is no significant difference between the numbers being tested.

Table 1

		Species	# of plots	Mean Number of trees
1) Large Seedling		OT	69	2.05290A
Height (ft)		RM	69	1.94884A
		RO	69	1.38942B
		WO	69	1.31725B
2) Large Seedling		OT	69	2851.9A
Stems (stems/acre)		RM	69	874.8B
		RO	69	373.9C
		WO	69	247.5C
3) Sapling		OT	69	11.4507A
Height (ft)		RM	69	10.2968A
		RO	69	3.6099B
		WO	69	.5652C
4) Sapling		OT	69	284.93A
Stems (stems/acre)		RM	69	266.96A
		RO	69	8.55B
		WO	69	1.16B

Mean number of trees[a] for large seedling and sapling categories. Four separate tests are shown using the mean number of trees. [a]Means followed by the same upper case letter are not significantly different between species groups. The letters are read vertically and each of the four tests is read independently from the other tests. OT= others, RM= red maple, RO= red oak, WO= white oak (Duncan's MRT, p=.05)

The second grouping of tests focused on how the different crown class openings affected the seedling numbers. Once again the Duncan's MRT test was used to see if there was a significant difference between the numbers. These tests focused how the species numbers were affected by the canopy openness (Table 2). The data showed there is a significant difference in the numbers for large seedling stems, sapling height and sapling stems between the species for all the different canopy opening categories. There is also a significant difference in the large seedling height but the heights are still relatively close to one another. The results from these tests reinforce the first group of testing. In the sapling stage it can be clearly observed from the calculations that oaks are statistically lower in height and number of stems compared to red maple and other species. While in the large seedling category the oaks are lower in numbers and stems compared to the red maple and others category but they are still competitive at this young age. So from the large seedling to the sapling stage this is where the problem is occurring with oak regeneration.

Table 2

1) Large Seedling						
Height (ft)	Canopy Opening	OT	RM	RO	WO	# of plots
	10	2.0093 aA	2.1150 aA	1.2564 aB	1.3857 aB	28
	20	2.0558 aA	1.7603 aB	1.4282 aC	1.3388 aC	33
	30	2.1938 aA	2.1450 aA	1.0725 aB	1.6113 aB	8
2) Large Seedling	Canopy Opening	OT	RM	RO	WO	# of plots
Stems (stems/acre)	10	2887.1 aA	770.0 aB	260.0 aB	371.4 aB	28
	20	3068.5 aA	943.0 aB	267.9 aB	357.0 aB	33
	30	1835.0 aA	960.0 aB	120.0 aC	452.5 aB	8
3) Sapling	Canopy Opening	OT	RM	RO	WO	# of plots
Height (ft)	10	10.361 aA	12.050 aA	.196 aC	5.156 aB	28
	20	10.708 aA	11.582 aA	.697 aC	2.900 aB	33
	30	8.376 bA	8.814 aA	1.313 aB	1.125 aB	8

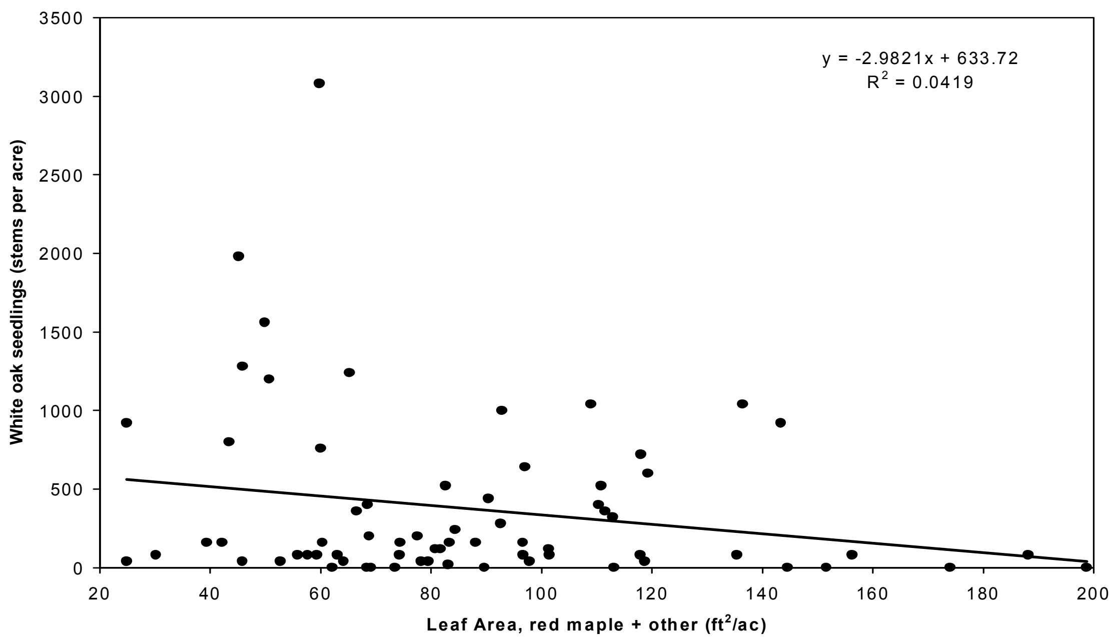
4) Sapling	Canopy Opening	OT	RM	RO	WO	# of plots
Stems (stems/acre)	10	251.43 bA	270.00 aA	.71 aB	10.00 aB	28
	20	266.36 bA	232.12 aA	1.21 aB	9.09 aB	33
	30	478.8 aA	400.0 aA	2.5 aB	1.3 aB	8

Four different tests calculated from the numbers from the crown class openings[b] categories. [b] Means followed by the same lower case letter are not significantly different between canopy opening. Means followed by the same upper case letter are not significantly different between species groups. OT= others, RM= red maple, RO= red oak, WO= white oak (Duncan's MRT, p=.05)

On closer comparison of the categories of Table 2 some similarities can be observed as the canopy openings become greater. The trend for the seedling class was as the canopy openings increased the heights of seedlings increased and the number of stems decreased. This occurred for the other species and the white oak, while the red maple and red oak did not show a trend. Then in the sapling category, white oaks were less in number as the canopy became more open, while for the red maple and other species the height decreased and the stem numbers increased. The number for red oaks in the sapling stage was too low to show a trend. Table 2 also shows that the white oak has higher regeneration numbers and height of seedling compared to the red oak in both the seedling and sapling stages. According to the data, red oak is present in the seedling stage but almost non-existent in the sapling category. These similarities in Table 2 seem to show trends but the results were not universal for all plots just the majority. Farther testing will need to be conducted to support these findings.

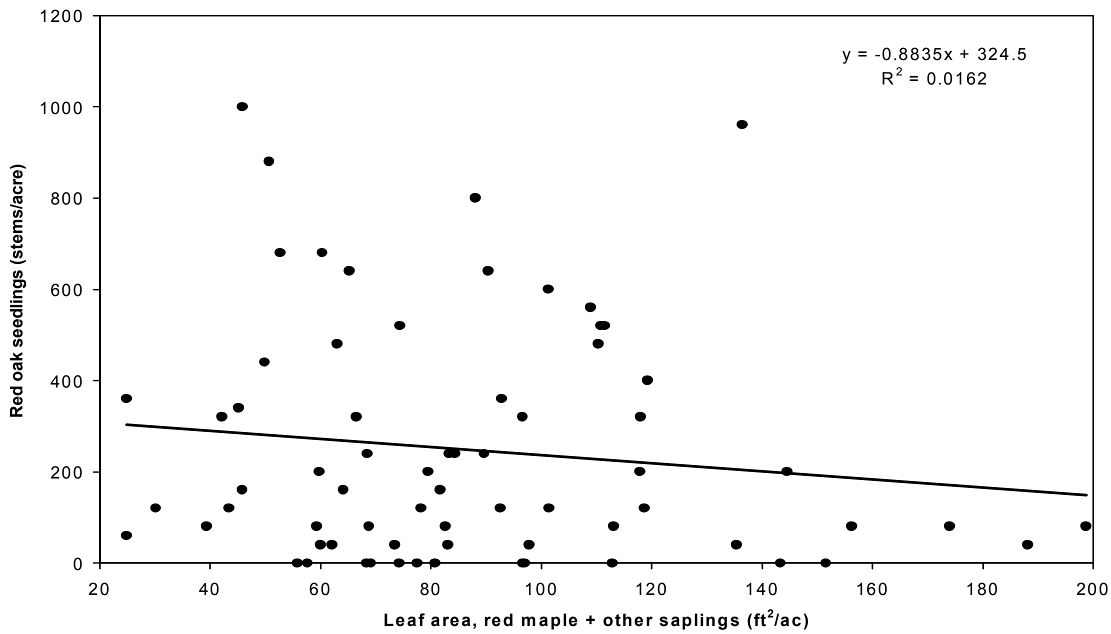
The third set of tests looked at canopy surface area regression models of oaks compared to red maple and other species. These models were run through the SAS System. The regression models used the minimum and maximum crown surface area numbers of seedlings and saplings from all 69 plots. The first crown surface area regression focused on the effects of red maple and other species on the number of white oak seedlings present in the understory (Figure 3). The graph illustrates as the numbers of red maple and other species increases the number of white oak seedlings decrease. The crown surface area by red maple and other species causes too much competition for the white oak, causing the seedlings to be less in number. The red oak seedling numbers showed the same tread as the white oak (Figure 4).

Figure 3



Crown surface area regression of how the total number of red maple and other species affect the numbers of white oak seedlings.

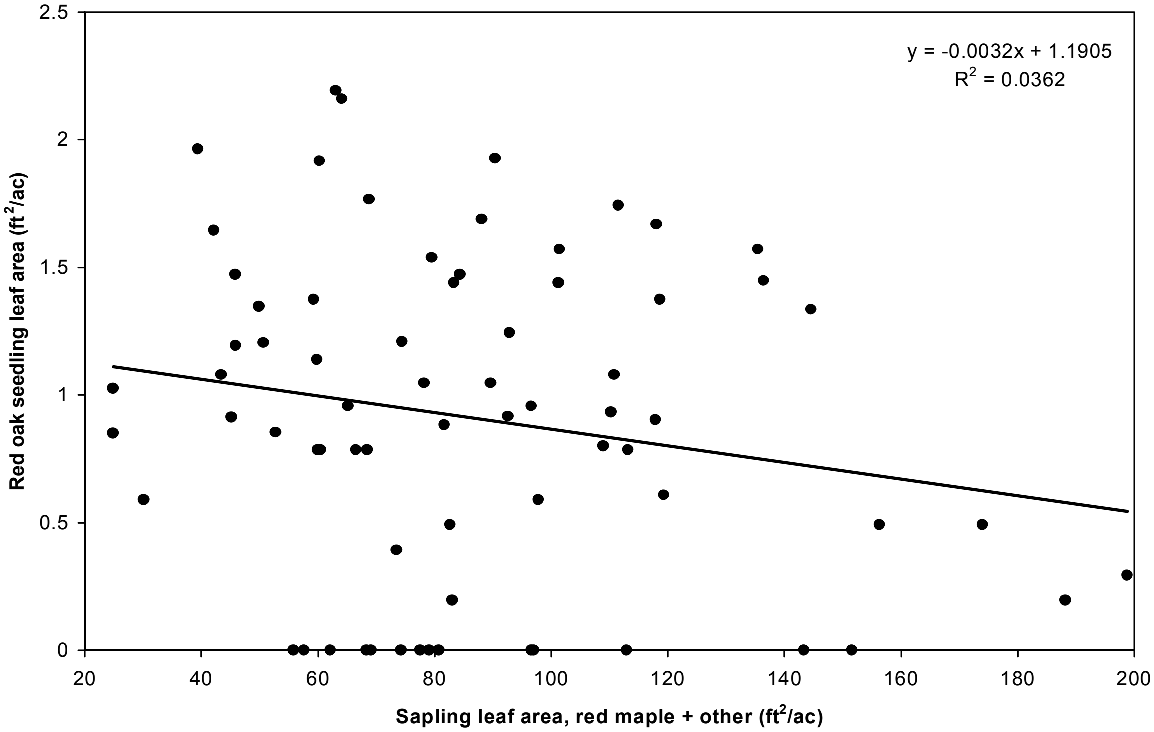
Figure 4



Crown surface area regression of how the total number of red maple and other species affect the numbers of red oak seedlings.

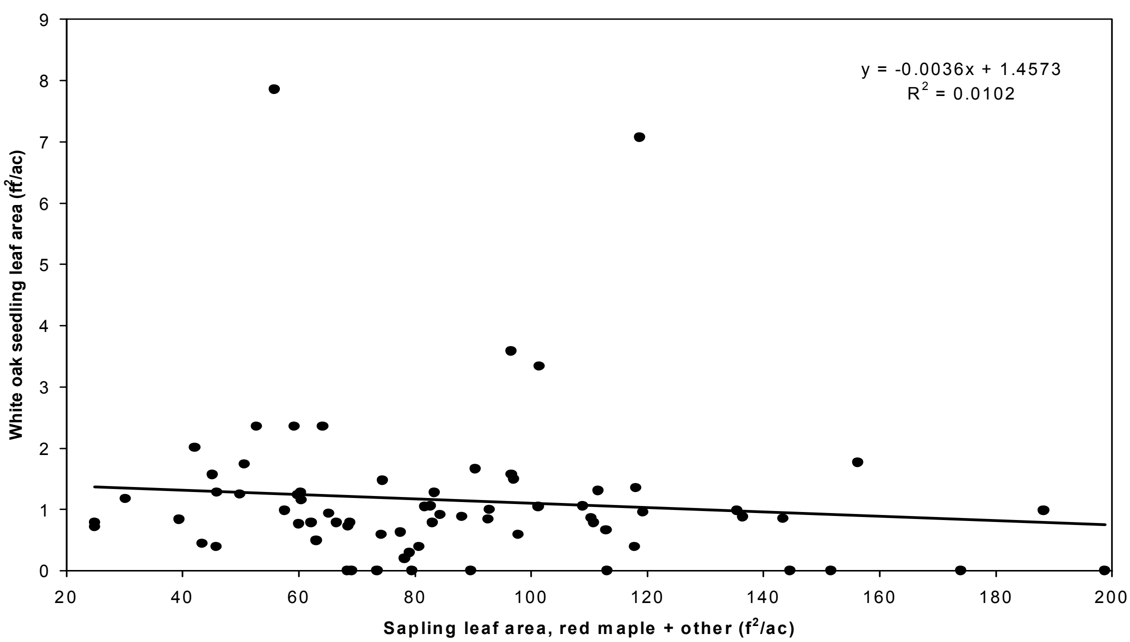
The second crown surface area regression model showed how the seedling crown surface area of the oaks compare to the crown surface area of the sapling red maple and other species crown surface area (Figure 5). The graphs for this regression show similar results as to the previous graph. As the crown surface area of the red maple and other species increases, the red oak crown surface area decreases. This trend is the same for the white oak seedlings, except for the white oak has lower numbers of crown surface area (Figure 6).

Figure 5



Crown surface area regression illustrating how red oak seedling crown surface area is affected by the sapling crown surface area of red maple and other species.

Figure 6



Crown surface area regression illustrating how white oak seedling crown surface area is affected by the sapling crown surface area of red maple and other species.

Conclusions

On the study sites the red oak and white oak are still the dominant species in the canopy. In both Zaleski State Forest and Richland Furnace State Forest the oak species are present in the large seedling stage category. But the oak seedlings are unable to compete with the other species and as an effect have a high mortality rate in the first few years after germination. This is the main reason to the lack of oaks in the sapling stage.

According to the Duncan's MRT test the stems per acre and average heights of the white oak and red oak seedlings and saplings are significantly different from the red maple and other species. But with closer inspection and comparing the actual numbers used in the graphs, there is a trend that can be observed. This trend is that there are oak seedlings in the understory and the trees seem to have competitive numbers with the non-oak species. But then in the sapling category the oak numbers greatly diminish and are overtaken by height and stems per acre by the competing vegetation. This is where the main problem is occurring, with the competing vegetation. The canopy closure seems to have an affect on the competing vegetation. The numbers showed a few trends but the research needs to be expanded to include more plots to ensure the findings of this report are correct and accurate. According to the calculations in the sapling category as the crown openings increased the saplings became shorter in height and greater in number. The height difference could be due to the increased amount of sunlight the trees receive causing them to branch out faster, since the trees do not need to compete for the sunlight. On the other hand, as the canopy becomes denser the trees need to compete to reach the sunlight so the trees are then taller in height. These are the results and trends that seem to be evident in the research.

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